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Urban Bee Diversity in a Small Residential Garden in Northern California

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Abstract.—Bee species diversity is known to be high in numerous urban areas worldwide. In California our research group from the University of California at Berkeley and Davis has been conducting surveys statewide of urban bee species and their preferred host plant flowers since 2005 and find that many cities also have high species diversity. In this paper we examine in some detail the bee-flower relationships in one small residential garden in northwestern California – Ukiah in Mendocino Co. In this garden, which is densely packed with preferred bee plants, we have recorded 68 bee species; citywide, Ukiah has 91 recorded species. High bee diversity in the garden is believed to be related to the high diversity and abundance of plant materials that provide a continuous source of pollen and nectar during the entire growing season. Bee visitation counts on selective (target) plant types indicate the bee-flower relationships are relatively predictable, and this information can be used to plan and establish bee habitat gardens.

Studies on diversity of bee species in urban environments worldwide have been increasing in recent years (see reviews in Cane 2005; Hernandez et al. 2009b). Some of these studies have undoubtedly resulted from research to document more of Earth's biodiversity, even in environments that have been severely disturbed by human activities and development. Increasing also are popular and semi-technical publications that provide objective biological profiles on the wide variety of organisms that live with us in the ever-expanding city environments (Grissell 2001; Lowry 1999, 2007; Tallamy 2009). In an earlier and relevant volume, Owen (1991) produced an extraordinary account of 15 sequential years of documenting the biodiverse organisms that came to visit her small residential garden in Leceister England. She also points out the significance of gardens for conserving wildlife. Thus, there is a definite new trend or movement towards recognizing interesting and desirable urban fauna and how to encourage and enjoy these organisms that frequent and establish in our gardens (Hayes 2003; Carroll and Salt 2004; Stone and Barlow 2005; Louv 2008; Tallamy 2009; Frankie et al. 2009).

The University of California at Berkeley and Davis have been surveying urban bees in California since the late 1990s with the general goal of increasing knowledge about a group of common insects that have established ecological relationships with gardens and have gone largely unnoticed, until recently, when the value of all bees became better known through Colony Collapse Disorder (CCD) of our important honey bees (NRC 2007). Since 2005 our research group has focused on a statewide survey of urban bee diversity and ecology, especially with regard to preferred ornamental host flowers. The first paper on this work (Frankie et al. 2009) provides an

overview of our findings through 2007. As this work continues it is clear that urban areas can support a rich assortment of bee species if the right floral and other resources are present (Ahrne et al. 2009).

In this paper we present findings from one of the gardens in the city of Ukiah, Mendocino Co. in northwestern California where there is rich diversity of plants and native bee species. Goals of this paper are first, to examine in some detail the floral relationships of garden plants (origin, flowering season, pollen/nectar resources) to local native California bee species over the period 2005 through 2008. Second, to compare the bee findings of the study garden with bee totals for the rest of Ukiah.

Site description: Ukiah Garden.—The city of Ukiah (pop. 15,497, as of 2000; elevation ~186 m) is located in Mendocino Co. in northwestern California in a large valley surrounded by low elevation mountains (up to ~1,065 m in elevation). Most of the city is in the western half of the valley, including the study garden. The eastern half of the valley is largely agricultural with pear orchards and vineyards. Almost all houses and gardens in Ukiah can be considered residential, and in most lots land has been cleared and houses and gardens established. Because Ukiah is inland and somewhat isolated by mountains, summers are hot and dry, but with cool evenings. Winters are mild to cold with occasional periods of frost and freezing temperatures, which has limited the use of some ornamental plant materials in the area.

As in almost every California city, urban residents in Ukiah use a high percentage of non-native plant materials in their gardens (Frankie et al. 2005, 2009). In this regard, the study garden is no exception as about 75% of its ornamental plants are non-natives (Table 1). The garden is unique, however, in that it contains a relatively high diversity of plant materials compared to others surveyed throughout the city. The garden was first planted in 2004, and selection of ornamental plants was based on the organic garden at the Fetzer winery in nearby Hopland (~16 km SSE of Ukiah). Fortuitously, most of the selected plant types are attractive to local bees.

The Ukiah garden was like most gardens in urban California, that is, dynamic with some plants progressively added and others removed over the period 2005-present. Most plant types were perennial and planted on a thick layer of topsoil that was originally brought to the garden in 2004. The closest natural area is 400+ meters to the west where houses stop at the edge of an extensive and dense oak-woodland habitat that occurs on a steep mountain hillside. Important bee plants such as *Arbutus menziesii* Pursh and several *Arctostaphylos* and *Ceanothus* species are widely scattered in this habitat. Open grassland is rare on the hillside. Westward within a km of the study garden are a few small, scattered patches of chaparral vegetation; within two km are larger patches. About five km east of Ukiah is the Mayacmas Range of mountains that is predominated with well developed and diverse chaparral vegetation. The entire wild area around Ukiah is filled with many native wildflower species (Stearns 2007).

The main part of the Ukiah garden was south facing in the front of the house and measured ~100 m^2 (10 m × 10 m). Two pathways traversed the garden and met at a front gate. A small narrow strip of garden was located on the east side of the house, which measured ~20 m^2. The vast majority of bee plants were found in the front yard. Plants in both the front and side yards received regular watering, pruning, and weeding. In the front yard plants were packed tightly in this relatively small space (Fig. 1). Plants in the side yard were spaced more widely.

MATERIALS AND METHODS

Bee and plant survey work at the Ukiah garden was initiated during the summer of 2005; three visits were made that year. In subsequent years visits were made several

times during the entire growing season: 2006 (9 visits), 2007 (13), and 2008 (12). Bee collections and bee frequency counts were made each year.

Voucher bee species were collected with aerial nets from all garden flowers that showed attraction to bees. Collected bees were transported to the lab at UC Berkeley, curated and sent to the bee lab at UC Davis to be identified by R. Thorp. Records of identified bees are kept on file in both labs; curated bees are permanently housed at UC Berkeley.

Bee frequency counts were made on selected (target) plant types in order to track bee diversity and abundance through time (see coded plants in Table 1). Patches (~1–1.5 m square) of target plant types in good flower were observed for three-minute periods, and each bee that made contact with reproductive flower parts was counted. Once counted on the first flower visited, they were not counted again, which allowed for focus on any new bee(s) entering the patch. Numerous bee counts were made on target plants during each year when the main bloom period occurred. Some bee taxa could be identified on the flowers, whereas others had to be collected to confirm identification. Counts provided bee diversity and abundance measures that were tallied and averaged for each plant type (Frankie et al. 2005, 2009). In this paper we focus on bee diversity measures. Future papers will be concerned with abundance measures for the study garden and the entire city of Ukiah.

Most target plants chosen in this study were the same ones used in an ongoing statewide survey of urban bees and their host flowers (Frankie et al. 2009). Because several target plants were either missing or in limited numbers, we added these plants in 2007 and 2008 to record bee activity (see coded plants in Table 1). Most added plants provided useful information, but a few such as *Encelia californica* Nutt., *Salvia* 'Indigo Spires', and *Duranta erecta* L. survived only one season. These species were not adapted to the cold temperatures that occur during winter in Ukiah.

RESULTS

We recorded all plant types (55) found in the garden that showed attraction to bees over the period of 2005–2008 (Table 1). There were a very few others that did not attract bees (e.g. ornamental grass) or were non-reproductive; all of these were small in size and not recorded. As indicated in Table 1, bees were attracted to plants in 19 different families with Asteraceae and Lamiaceae having the greatest number of representative species (15 each). Members of these two families together represented almost 55% of the plant types in the garden. Frankie et al. (2005) also found plants in these two families to be the most important sources of pollen and nectar in two San Francisco Bay Area cities.

The 55 plant types listed in Table 1 consisted of 14 California natives (25%) and 41 non-natives (75%). Together they provided pollen and nectar for bees during each month of the year (Wojcik et al. 2008). Further, many of the plants have long flowering periods, some of which spanned two seasons. Examples of these included *Bidens ferulifolia* DC., *Coreopsis grandiflora* cvs, *Cosmos bipinnatus* Cav., *Erigeron glaucus* Ker Gaw., and *Solidago californica* Nutt. for pollen and nectar, and *Lavandula* sp. 2, *Nepeta* × *faassenii* Bergmans, *Perovskia atriplicifolia* Benth., *Salvia uliginosa* Benth., and *Linaria purpurea* (L.) Mill. for nectar. This resource continuity, which results in several plant types being in flower simultaneously, is believed to be one of the main factors sustaining diverse bee species during the growing season.

Bee taxa collected at the Ukiah garden from 2006 through 2008 are listed in Table 2. To date, 68 species in 26 genera and five families have been recorded, with most species in the families Megachilidae (32) and Apidae (19). Collections of bee species increased during each year (30, 40, 53

respectively), and this was related, in part, to more visits made in 2007/2008 than 2006 and to the added bee-attractive plants during the latter two years (Table 1). The overall list of bee taxa recorded from this and other Ukiah gardens for the study period was 91 species in 28 genera and five families.

Bee seasonality.—Many of the bee species had seasonal patterns of occurrence, that is, spring, summer, or both seasons (Table 2). Additional ongoing collections are considered necessary for characterizing more precisely the seasonality for most species, however, some patterns are presented here that are well known for selected genera/species in northern California.

There were several groups of spring-season bee taxa (Table 2). The most prominent groups were in the genera *Andrena* (Andrenidae) and *Osmia* (Megachilidae). The two *Andrena* species, *A. auricoma* Smith and *A. cerasifolii* Cockerell, were exclusively spring bees, and 10 of 12 recorded *Osmia* species were spring bees. One of 12 *Osmia* was a spring/early summer species; *Osmia regulina* Cockerell was a summer bee. In the Apidae, *Anthophora californica* Cresson, *Eucera frater albopilosa* (Fowler), and *Habropoda depressa* Fowler are well known spring bees. *Bombus* species (4) are primitively eusocial and thus multiple season bees, but most were in relatively high abundance during this period. Although three of four species were also collected in summer, their frequencies were substantially lower. This is probably due to the fact that two species (*B. melanopygus* Nylander and *B. vosnesenskii* Radoszkowski) start their nests in January and peak in early spring.

The most prominent group of summer bees was in the genus *Megachile* (Megachilidae). Seven of nine listed species were collected in summer. Two of the nine, *M. apicalis* Spinola and *M. rotundata* (Fabricius), which were introduced in California, were found during both seasons. Only one species, *M. lippiae* Cockerell, was collected in spring. In the Apidae, *Melissodes robustior* Cockerell was a summer bee; *M. lupina* Cresson, although rarely collected, was also a summer bee.

Numbers of plant types visited by each bee species were compiled and sorted to California natives and non-natives (Table 2). We also arbitrarily divided the bees into two groups: species that visited relatively few host plant types (1–4 natives plus non-natives), and those (5 and above) that had a wider host range. In the first group there were 54 bee species and the vast majority of them (41) were collected on only one or two hosts. The second group had 15 species, which included all four of the introduced species, *Apis mellifera* Linnaeus, *Hylaeus punctatus* (Brulle) (Colletidae), *Megachile apicalis*, and *M. rotundata*. As expected the host range of *A. mellifera* was the highest with 21 plant types visited, followed by *M. rotundata* with 12 host types. The three California native bee species with the widest host ranges were *Halictus ligatus* Say (Halictidae) (10 plant types) and two apids, *Xylocopa tabaniformis orpifex* Smith (9 types) and *Ceratina acantha* Provancher (8 types). It is noteworthy that California native bees in the second group (11 of 15 species) were collected more frequently (10 of 11 species) on non-native host plants.

Plant–bee relations.—Some plant species had an unusual capacity to attract high bee diversity. We examined this capacity in native and non-native plant types having the greatest bee diversities (Table 3). In the natives, *Carpenteria californica* Torr., *Solidago californica* and *Erigeron glaucus* had the highest bee species diversities. In non-native plants, bee species counts were higher than natives in four of five plant types. Most attractive non-natives are nectar resources in the Lamiaceae. Except for *C. californica*, which has a relatively short flowering period (May), the long blooming periods of the other nine plants (Table 3) allowed them to be exposed longer to a greater diversity of bee species. All but *C. californica* bloomed for at least three months. This phenological character-

Table 1. Continued.

Plant species or cultivars (cvs)	Plant Origin[1]	Flowering Period[2]	Floral Reward[3]
Plantaginaceae			
Antirrhinum majus L.	Non-Nat	Spr	?N/P
Polygonaceae			
Eriogonum grande Green var. *rubescens* Munz	Nat	Sum	N
Eriogonum umbellatum Torr.	Nat	Spr-Sum	N
Ranunculaceae			
Aquilegia sp.	Non-Nat	Spr	N
Rutaceae			
Ruta graveolens L.	Non-Nat		N
Scrophulariaceae			
Linaria purpurea (L.) Mill.[4,5]	Non-Nat	Sum-Fall	N
Penstemon digitalis 'Husker's Red'	Non-Nat	Spr	N
Penstemon 'Midnight'	Non-Nat	Spr	N
Penstemon sp. (red flower)	Non-Nat	Spr	N
Penstemon heterophyllus S.Watson[4]	Nat	Spr	N
Verbenaceae			
Aloysia triphylla Royle	Non-Nat	Sum	N
Duranta erecta L.[4]	Non-Nat	Sum	N
Verbena bonariensis L.	Non-Nat	Sum	N
Total: 55 types (includes all cultivars)			

[1] Nat- California native plant; Non-Nat- not native to California flora
[2] Spr- Spring; Sum- Summer; Fall
[3] N- Nectar; P- Pollen
[4] Plants progressively added to garden over period 2006–2008
[5] Bee frequency counts were collected on these target plants

istic coupled with their inherent attraction (Frankie et al. 2005, 2009) probably accounts for part of the higher diversity levels.

A relationship between flower patch size and bee diversity was also suggested from results presented in Table 3. It appears that large patch size of some bee-attractive plant types may attract high bee diversities. In the case of two natives, *Carpenteria californica* and *Solidago californica*, and the first four non-native plant types (Table 3), all had patches of more than 1.5 m^2 of flowering space. Frequency counts in subpatches (~1–1.5 m^2) in all but *Carpenteria californica* (Table 1) were used to determine the high bee diversities in each of these selected species. Experimental studies will be needed in the future to further examine this relationship.

Many plant types flowered simultaneously during any given time period. The seasonal bee species sort themselves among simultaneously flowering types in relatively different and predictable patterns (Frankie et al. 2009). Numerous bee frequency counts that have been gathered over three years of monitoring exemplify how summer flowering *Solidago californica*, *Erigeron glaucus*, and *Perovskia atriplicifolia* attracted different bee groups during coinciding flowering periods. In descending order of occurrence, *Solidago* attracted mostly halictids, then honey bees, non-*Osmia* megachilids, and *Ceratina* species. *Erigeron* attracted non-*Osmia* megachilids, halictids, and *Ceratina*. *Perovskia* attracted mostly honey bees, then non-*Osmia* megachilids, and *Ceratina* species (Fig. 2). *Nepeta* × *faassenii*, which flowers extensively in both seasons attracted honey bees, *Ceratina* species, and non-*Osmia* megachilids in the summer, but in spring the same *Nepeta* plants attracted somewhat different bee species and frequencies: honey bees, *Bombus* species, and *Osmia* species. Thus, on a

Fig. 1. Ukiah study garden during a spring bloom.

given summer observation day, when all four plant types are in flower, one can expect certain frequencies of bee taxa on one plant type and different sets on the other three host plant types.

Simultaneous flowering of several species had another behavioral-ecological effect that was first observed during the survey of bee-attractive plants in two San Francisco Bay Area cities from 1999–2003 (Frankie et al. 2005). Some plant species that are usually unattractive to bees such as *Achillea millefolium* L., *Erigeron karvinskianus* DC., and *Verbena bonariensis* L. become attractive when diverse and attractive flowering species surround them. Apparently, bees will try out these plants because of their close proximity to attractive plants. Once tested, these "unattractive plants" become attractive. We have observed this phenomenon previously in other surveyed California gardens, for example, in Sacramento and La Canada Flintridge (near Pasadena).

Ukiah Garden versus Greater Ukiah

Four bee taxa in the Ukiah garden were compared and contrasted with the same taxa from collections made in other gardens throughout the city of Ukiah where a total of 91 species have been recorded to date. These taxa were selected because they provide insight on host plant factors that may be responsible for the extant bee list at the Ukiah garden.

Osmia.—*Osmia* species are well represented with 12 of the 15 city species found in the garden. The most important host plants in the garden were *Lavandula* sp. 2, *Linaria purpurea*, and *Nepeta* × *faassenii*. Citywide, *Osmia* were also found on *Phacelia tanacetifolia* Benth.

Andrena.—Only two of 10 city species were found in the garden. Examination of

host records clearly indicates that *Andrena* species not found in the garden were associated with mostly California natives: *Ceanothus* species and *Arbutus menziesii*, neither of which are in the garden. One of the city *Andrena* species was found on flowers of the non-native *Philadelphus coronarius* L. (sweet mock orange). Other researchers have also noted a scarcity of *Andrena* in urban gardens (Antonini and Martins 2003; Fetridge et al. 2008).

Agapostemon texanus Cresson is one of the most common bee species found on a variety of urban host plants in California (Frankie et al. 2009), however, we have yet to collect it in the Ukiah garden. In greater Ukiah it was only collected once on chicory flowers.

Lasioglossum.—Only five species were found in the garden, yet 12 species have been collected throughout Ukiah on plants of *Ceanothus* sp., *Eschscholzia californica* Cham., *Ceanothus* 'Julia Phelps', *Convolvulus arvensis* L., and *Centaurea solstitialis* Asso. None of these plant types were in the study garden.

DISCUSSION AND CONCLUSIONS

Although the study garden had a high diversity of bee species, numbers could have been higher if more aggressive sampling methods had been used, for example pan traps (Wojcik et al. 2008; Hernandez 2009b), vane traps (R. Thorp pers. com.), and with earlier season visits (Feb./Mar.) and more frequent monitoring intervals of every two to three weeks. Further, if more host plants of other bee species were added, it would also probably increase bee species diversity. In this regard, adding *Ceanothus* shrubs or *Arctostaphylos* species to the garden would likely result in more *Andrena* species to the former and increased abundance of *Bombus* and *Anthophora* species to the latter. *Ceanothus* 'Julia Phelps' and *C.* 'Dark Star' were just added in June 2009, and two *Arctostaphylos* species in an adjacent fallowed lot to the study garden are scheduled for monitoring in early 2010. Thus, high diversity of the right plant types flowering in sequence over a growing season can result in high bee diversity in the Ukiah area.

This relationship of preferred high plant diversity to high bee diversity was also demonstrated at the University of California, Berkeley Oxford Tract where in 2003/2004 a specially constructed garden was designed to provide preferred pollen and nectar of ornamentals to local native bees for the entire growing season (Wojcik et al. 2008; Hernandez et al. 2009a). At the end of the growing season in 2004, the plants had attracted 37 bee species (Hernandez 2009a). Additional sampling since then has added seven more species to the list (R. Thorp and J. Hernandez, pers. com.). Other gardens in the state (Frankie et al. 2009) that fortuitously provide preferred bee plants during the growing season are found in Sacramento (Masonic Lawn Cemetery with 69 bee species) and La Canada Flintridge (Descanso Gardens with 94 bee species).

Most surveyed urban areas in California have diverse floral resources that diverse native bees need for reproduction and survival (Frankie et al. 2009). There are a few urban areas, however, where the right plant types for native bees are scarce, widely scattered, or nonexistent, and this pattern seems to reflect local gardening practices and plant selections (B. Ertter, UC Berkeley Jepson Herbarium, pers. com.). In these few urban areas, which include the cities of Monterey-Carmel-Pacific Grove, Paso Robles, and San Diego, preferred bee plants are scarce and widely scattered as are the native bee species (G. Frankie, unpub.).

In the case of Ukiah and other California cities, most plants used in gardens are non-natives to the state. Although native California bees coevolved with certain native plants, many have the capacity and flexibility to use a variety of plants, including some non-natives. A preliminary survey of native versus non-native bee plants in Berkeley revealed that of the 1000+ plant types used in this city, only ~50 were natives; ~950 were non-natives.

Table 2. List of bee taxa collected at Ukiah garden from 2006–2008. Numbers of California native and non-native plant types visited by each bee species are listed respectively in parens.

Bee species	2006	2007	2008	Bee Season[1]
ANDRENIDAE				
Andrena auricoma Smith (1,1)			+	Spr
Andrena cerasifolii Cockerell (1,0)			+	Spr
APIDAE				
Anthophora californica Cresson (0,1)		+	+	Spr
Anthophora urbana Cresson (0,1)	+	+	+	Spr/Sum
Apis mellifera Linnaeus[2] (5,16)	+	+	+	Spr/Sum
Bombus californicus Smith (0,1)		+		Spr
Bombus flavifrons Cresson (1,3)	+	+	+	Spr/Sum
Bombus melanopygus Nylander (1,4)		+	+	Spr/Sum
Bombus vosnesenskii Radoszkowski (0,3)	+		+	Spr/Sum
Ceratina acantha Provancher (2,6)	+	+	+	Spr/Sum
Ceratina nanula Cockerell (1,3)	+	+	+	Spr/Sum
Ceratina sequoiae Michener (0,1)		+	+	Sum
Ceratina tejonensis (1,3)	+	+	+	Spr/Sum
Eucera frater albopilosa (Fowler) (0,1)		+	+	Spr
Habropoda depressa Fowler (0,2)		+	+	Spr
Melissodes lupina Cresson (1,0)	+			Sum
Melissodes robustior Cockerell (0,6)	+	+	+	Sum
Melissodes tepida timberlakei Cockerell (1,3)	+	+	+	Spr/Sum
Nomada sp. CM (0,1)			+	Spr
Nomada sp. F (1,0)			+	Spr
Xylocopa tabaniformis orpifex Smith (1,8)	+	+	+	Spr/Sum
COLLETIDAE				
Colletes kincaidii Cockerell (1,0)			+	Sum
Hylaeus episcopalis (Cockerell) (0,1)		+		Spr
Hylaeus mesillae Cockerell (3, 6)	+	+	+	Spr/Sum
Hylaeus polifolii (Cockerell) (1,2)		+	+	Sum
Hylaeus punctatus (Brule)[2] (5,0)	+	+	+	Spr/Sum
Hylaeus verticalis (Cresson) (0,1)		+		Sum
HALICTIDAE				
Halictus farinosus Smith (2,4)	+	+	+	Spr/Sum
Halictus ligatus Say (4,6)	+	+	+	Spr/Sum
Halictus tripartitus Cockerell (3,4)	+	+	+	Spr/Sum
Lasioglossum incompletus (Crawford) (1,0)			+	Sum
Lasioglossum tegulariformis (Crawford) (1,2)			+	Spr/Sum
Lasioglossum (Dialictus) sp. F (0,1)			+	Sum
Lasioglossum (Dialictus) sp. 2 (0,1)	+			Sum
Lasioglossum (Evylaeus) sp. (1,0)	+			Sum
Sphecodes sp. CM (1,0)			+	Sum
MEGACHILIDAE				
Anthidiellum notatum robersoni (Cockerell) (0,1)	+		+	Sum
Anthidium illustre Cresson (0,1)			+	Sum
Anthidium placitum Cresson (0,1)			+	Sum
Ashmeadiella cactorum basalis Michener (0,1)		+		Sum
Ashmeadiella timberlakei solida Michener (0,1)			+	Spr
Coelioxys apacheorum Cockerell (0,1)		+		Sum
Dianthidium ulkei (Cresson) (3,2)	+		+	Sum
Dolichostelis laticincta Cresson (0,1)		+	+	Sum
Heriades occidentalis Michener (2,3)	+	+	+	Spr/Sum
Hoplitis producta gracilis (Michener) (0,1)			+	Spr
Megachile angelarum Cockerell (0,4)	+	+	+	Sum
Megachile apicalis Spinola (0,5)	+	+	+	Spr/Sum
Megachile coquilletti Cockerell (0,1)		+		Sum

Table 2. Continued.

Bee species	2006	2007	2008	Bee Season[1]
Megachile fidelis Cresson (1,5)	+	+	+	Sum
Megachile frugalis Cresson (0,3)		+	+	Sum
Megachile gentilis Cresson (1,2)	+			Sum
Megachile lippiae Cockerell (1,0)			+	Spr
Megachile montivaga Cresson (0,1)		+		Sum
Megachile rotundata (Fabricius)[2] (3,9)	+	+	+	Spr/Sum
Osmia aglaia Sandhouse (0,1)			+	Spr
Osmia calla Cockerell (0,1)		+		Spr
Osmia coloradensis Cresson (2,2)		+	+	Spr
Osmia cyanella Cockerell (1,3)	+	+	+	Spr
Osmia densa Cresson (0,1)		+		Spr
Osmia gabrielis Cockerell (0,1)			+	Spr
Osmia granulosa Cockerell (0,2)	+		+	Spr/Sum
Osmia lignaria propinqua Cresson (0,1)		+		Spr
Osmia montana Cresson (1,0)			+	Spr
Osmia nigrifrons Cresson (0,1)			+	Spr
Osmia regulina Cockerell (1,2)	+		+	Sum
Osmia sp. A (0,1)		+		Spr
Protosmia rubifloris (Cockerell) (2,2)	+		+	Spr/Sum
Species Totals:	30	40	53	
Totals for all years: 5 families, 26 genera, 68 species				

[1] Spr-spring; Sum-summer
[2] Introduced bee species in California

Further, about 80% of the natives attracted bees at measurable levels, whereas slightly less than 10% of the non-natives attracted bees. Still, this 10% amounted to ~90 attractive plant types (Frankie et al. 2005). Further, many to most bee-plant relationships in Berkeley and most other gardens in the state are relatively predictable (Frankie et al. 2009). That is, certain bee taxonomic groups can be expected to be associated with given plant types, and this predictability allows for planning of bee gardens, which are now becoming more common in California and elsewhere (Pawelek et al. 2009). Other authors have also commented on the value of using native and non-native plants for pollinator gardens (Fetridge et al. 2008).

A synthesis of findings in this study suggests that in the case of Ukiah and probably several other California cities, planning for a highly diverse bee garden will depend on several plant factors including: 1) high plant diversity of the right native and non-natives, 2) a complete seasonal sequence of bee plants that provide a continuum of pollen and nectar, and 3) probably large flowering patch sizes of the most attractive plant types. Another key factor is availability of nesting substrates. Nesting bees have only rarely been observed in the Ukiah study garden, which suggests that most species probably came from outside the garden. In a relevant paper, Cane (2005) calls attention to the three needs of bees: floral resources, nesting opportunities, and "condition of the urban matrix." In the case of the Ukiah garden, condition of the urban (or environmental) matrix becomes all-important as it appears that most bees come from the surrounding area, which probably includes nearby wild areas.

Finally, updates on the California statewide survey of urban bee species and their preferred plant types can be found at our website: http://nature.berkeley.edu/urbanbeegardens. More than 225 bee species have been collected already from the surveyed cities of Redding, Ukiah, Sacra-

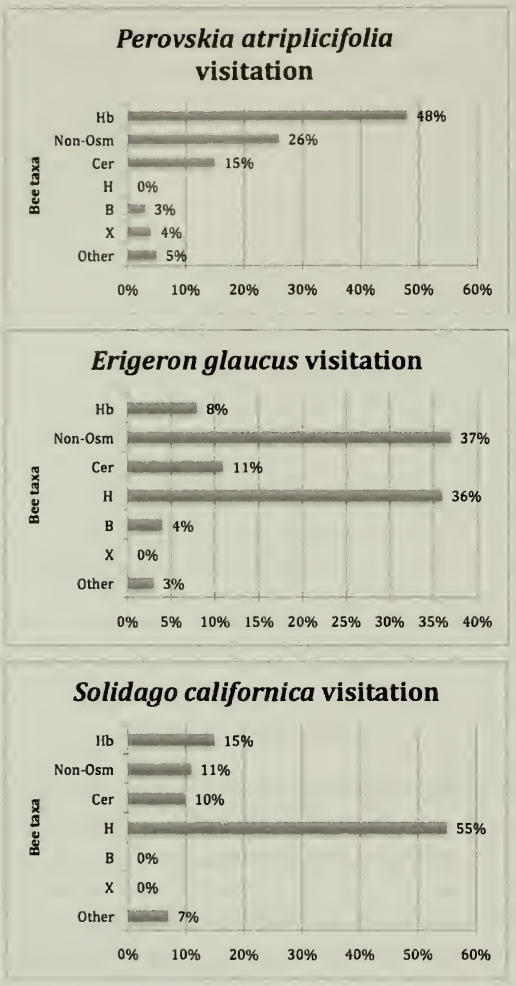

Fig. 2. Visitation percentages of main bee taxa to three host plant flowers. Percentages based on totals of bee frequency counts over study period: *Perovskia* (n= 54 counts), *Erigeron* (n= 32 counts), *Solidago* (n= 46 counts). Hb – honey bees, Non-Osm – non- *Osmia* megachilids, Cer – *Ceratina*, H – halictids, B – *Bombus*, X – *Xylocopa*, Other – bee taxa at lower % levels.

mento, Berkeley, and Santa Cruz in northern California, and San Luis Obispo, Santa Barbara, La Canada Flintridge, and Riverside in southern California. We expect the number of bee species collected in these cities to increase as sampling continues in 2009 and beyond. More than 1,600 species are known from the entire state.

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We dedicate this paper to Roy Snelling – a good friend and fellow bee biologist. Roy was always willing to help us with new and interesting bee taxonomic and behavioral/ecological problems. His enthusiastic and generous personality will be sorely missed.

Table 3. Native and non-native plant species attracting highest numbers of bee taxa in Ukiah garden, 2005–2008.

Plant species	Nos. of attracted bee taxa: Genera	Nos. of attracted bee taxa: Species	Flower Months
Natives			
Carpenteria californica Torr.	9	15	5
Solidago californica Nutt.	9	15	7 to 9
Erigeron glaucus Ker Gawl.[2]	9	12	5 to 10
Achillea millefolium L.	6	7	5,6,8,9
Grindelia hirsutula Hook. & Arn.[3]	4	4	5 to 8
Non-Natives			
Nepeta × *faassenii* Bergmans	14	28	5 to 10
Perovskia atriplicifolia Benth.	8	18	6 to 10
Lavandula sp. 2	11	17	6 to 8
Erigeron karvinskianus DC.	11	17	4 to 10
Aster × *frikartii*[3]	6	10	7 to 9

[1] Plants listed in decreasing order of diverse bee species.
[2] Mostly from added *E. glaucus* 'Wayne Roderick'
[3] Added plant species to garden - not previously in garden.

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